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# M198 TOWED HOWITZER PRODUCT IMPROVEMENT PROGRAM (PIP) OVERVIEW

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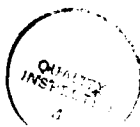
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## **INTRODUCTION**

An M198 Fielded System Review was completed September 1984. This review constituted a baseline for the development of the M198 Product Improvement Program (PIP). The areas being revised were a result of user concerns. Approval for the production and incorporation of the M198 PIP was granted by the AMCCOM Configuration Control Board on 8 September 1988. Fielding of the first production PIP kits are to begin August 1991. The purpose of this report is to provide an overview of the improvements being incorporated on the M198 Howitzers and the rationale for the selection of those solutions.

## **BRAKE SYSTEM**

### **Brake Precheck System**

Due to continuing problems experienced in monitoring the M198 brake system, a series of two gauges mounted on the howitzer's right trail was incorporated to help diagnose the weapon's brake problems (fig. 1). Presently the weapon's brake precheck involves standing between the trails and feeling for a protruding pin on the master cylinder's air side when the truck driver applies the brakes. This system, in many cases, is not effective because in the limited space available it is difficult to locate the protruding pin, and even if the pin is located, it is hard to determine if it is protruding the proper length. Another problem associated with the present system is that when checking for proper functioning of the system, the crewman is required to be standing between the trails. For obvious reasons this could be deemed a safety hazard. The new system allows the monitoring of the brakes from outside the trails. If a problem should exist, the easy-to-read gauges will help to determine where the problems exist, allowing for quick and proper repair.

The new precheck system includes a 0 to 200 psi gauge, which monitors the air side of the master cylinder, and a 0 to 3000 psi gauge, which monitors the hydraulic side of the master cylinder. The gauge which checks the air side of the master cylinder helps to determine the following:

- Is the truck providing adequate pressure (90 to 125 psi)?
- Are the brake lines hooked up correctly? (Lines should be crossed.)
- Gauge will show if there is any residual pressure in the system after the brakes are released. (This would lead you to believe that the relay valve or master cylinder, depending on whether one or both gauges indicate a pressure reading, may be sticking.)

- Are the brake lines damaged? (The gauges would indicate inadequate pressure.)

The gauge which monitors the hydraulic fluid pressure will determine if the master cylinder is working as intended.

The new brake precheck system with its color coded gauges will not only make the precheck procedure easier to accomplish, but it should also help reduce maintenance needed because the system will help diagnose where any problems exist.

### **Snorkel System**

Incorporated into the present M198 master cylinder assembly is a carbon steel filter breather which allows the master cylinder's air side of the assembly to breathe from the environment when the weapon's brakes are applied or released. The breather is equipped with a metal filter that has 40 micron rating. The purpose of the breather assembly is to prevent moisture build-up in the assembly. The problem with the present system is that when the brakes are released a vacuum is created and water and/or foreign matter is taken into the air side of the cylinder, depending on what environment is being experienced at the present time. This is undesirable because water in the air housing could lead to corrosion, and the intake of foreign matter could cause undesirable functioning of the assembly.

Because of the inevitable problems encountered, a design which allows the master cylinder assembly to do its breathing from within the right trail was incorporated. The design consists of a straight-in-line filter with 1/4 in. female ports. The filter is made with a low carbon steel housing and a paper filter element which has a 40 micron rating. The temperature rating for the assembly is -65°F to 145°F. The design also calls for the use of a blind rivet nut (similar to those presently used on the M198) which is to be installed into the right trail and a connection between the rivet and the filter is accomplished with a hose containing two male fittings.

To allow the snorkel system (fig. 2) to breathe into the trails, water must not completely fill the internal cavity within the trails. It was proven that the trails do not fill up with water by performing the tap water test. This test indicated that it was unlikely that the trails will fill up with water to the level of the hose inserted into the right trail during the required 5-minute submergence of the bottom carriage which is also a howitzer requirement. The snorkel system will allow for increased reliability while reducing the maintenance needed because of contaminants present in the assembly.

## **Tap Water Test**

Given or calculated data

Volume (up to hose level): 1.0574 ft<sup>3</sup>

Time: 5 min

Necessary flow rate to reach hose level: 1.58198 gal/min

## **Test Objectives**

This test was to determine if, over a 5-minute period the compartment containing the hose will fill with water up to the level at which the hose is placed. The success of this test indicated that the howitzer can ford streams while having the trails submerged for extended periods of time without the snorkel hose taking in water.

## **Brake Cover Addition**

In an effort to prevent damage to the snorkel system (filter and hose which runs into trail) and to the hoses which run to the precheck system gauges, an extension was added to the existing brake cover (fig. 3). This cover will prevent damage during towing maneuvers (underbrush) and when the troops are working between the trails.

## **Protection of Brake Lines**

The hydraulic lines on the M198 howitzer have proven to be susceptible to damage during normal use. The lines run along the weapon's trails, under the road arms, and along the back of the bottom carriage. Damage to these lines occurs when there is hardware and nonhardware incidents. While failure of these lines does not cause the weapon to be considered down, towing of the weapon can become difficult because the vehicle towing the weapon is now responsible for all of the braking (truck and howitzer). Restricting the flow of hydraulic fluid can contribute to brake dragging and fire. Reports have shown that the hydraulic tubing which runs along the back of the bottom carriage (fig. 4) is the brake line most often damaged. For this reason, the protection of this line was addressed.

Covers similar to those used to cover the hydraulic lines which run from the manifold assembly to the hydraulic hand pumps will be used to protect the line running along the back of the bottom carriage (fig. 5). The covers will provide protection to the hydraulic lines, by eliminating the damage to the lines from activity between the trails and from pulling loose from the bottom carriage.



## **Drain Valve**

Improvement of the drain valve was necessary to reduce operator effort, provide a positive locking position, and reduce brake failure resulting from air leaks. Two alternate designs were considered to replace the "T" handle design. An "L" handle design which increased leverage was unacceptable since the two-piece, brass assembly design leaked after several test cycles. A toggle valve (figs. 6 and 7) was selected due to the ease of operation and because after repetitive usage, no leakage occurred.

The toggle valve meets these essential design requirements:

- 150 psi working pressure range
- -55°F to 145°F temperature range
- 1/4 in., male pipe thread at the inlet
- 200 psi hydrostatic pressure test

Desired features of the toggle valve include:

- Positive open and close positions
- Improved operability

## **EQUILIBRATOR ADJUSTING SCREWS**

The troops have been experiencing difficulty operating the equilibrator adjusting screws. Incidents have been reported that as much as 190 ft-lb of torque was required to turn the screws with the gun tube at various elevations. Forcing the screw when difficulty is experienced has resulted in rounding or splitting of the bolt head and the inability for further adjustment.

The goal of this study was to obtain torque levels of under 60 ft-lb when the gun tube is in travel lock position (+250 mils). To accomplish this task, the following conditions were varied to predict their contribution to torque reduction.

- Change adjusting screw material from bronze to steel to reduce deflection
- Increase the bore diameter on the cover interfacing with the slide bracket
- Reduce coefficient of friction between moving parts by adding a bearing to the assembly and adding a friction reducing coating to the screw
- Increase the number of threads/in. on the adjusting screw

- Decrease the threaded diameter of the adjusting screw.

Changing the adjusting screw material from bronze to steel reduced the deflection of the screw. This change prevents the screw from bending at its neck, eliminating damage to the interfacing threads of the screw and slide bracket and the binding between the interfacing threaded slide bracket and its attaching guide. The material change was implemented since possible binding due to screw deflection was eliminated.

The bore diameter on the slide bracket cover was increased to eliminate binding between this cover and the top of the adjusting screw. This condition allows movement of the interfacing screw at this location. By increasing the bore diameter of the covers, all radial loads will be taken up by the slide bracket and not the cover. Therefore, any binding between the cover and screw is eliminated due to cocking of the adjusting screw.

The introduction of a bearing to the assembly and adding a friction reducing coating to the adjusting screw reduced the coefficient of friction between the moving parts. At high gun tube elevations, the bearing aides rotation between the adjusting screw and stationary cover. The solid lubricant coating, in particular electroless nickel plating impregnated with a fluorocarbon and molybdenum disulfide, added to the adjusting screw allows consistent and thorough lubrication of the screw with the interfacing slide bracket. Both the addition of the bearing to the assembly and the solid lubricant coating to the screw were used in the final assembly.

Analysis revealed that by increasing the number of threads/in. on the adjusting screw and interfacing slide bracket frictional forces were reduced by less than 1%. Although the effort per screw revolution is reduced because of the load being distributed theoretically over more threaded surface area, more turns of the screw would be required. Since the operating torque would not be significantly reduced by increasing the screw threads/in., this change was not accepted.

Although decreasing the threaded diameter of the adjusting screw from 1.25 to 5 acme thread to 1.00 to 5 acme thread reduced the torque required to adjust the screw by approximately 15%, this change was not implemented. The threaded diameter of the screw was not changed due to the added cost of replacing existing slide brackets and since the 60 ft-lb torque requirement was already met by the bearing and solid lubricant coating addition.

The recommended (fig. 8) and original design were tested, and operational torques were taken at various gun tube elevations (tables 1 and 2). It was demonstrated that the operating torques at upper elevations (+250 mil and above) were reduced by more than 50%. In conclusion, the desired 60 ft-lb operating torque at travel lock position (+250 mil) was met by the new adjusting screw assembly.

## HYDRAULIC SELECTOR VALVES

The selector valves used to control the raising and lowering of the howitzer's wheels and speed shift have been seizing because of corrosion of the valve shaft.

The failed valves are currently being replaced at a rate of approximately 120/yr and a cost of \$31,000 (\$258.33<sup>1</sup> per valve)/yr.

The plan was to look at two alternatives: rework the existing selector valve with a corrosion resistant conversion kit and replace all existing valves with a completely new corrosion resistant valve.

To obtain corrosion resistance, the decision was to use a 400 series, stainless steel shaft rotating inside of an olite bronze bushing that would be press-fit into the existing cast-iron housing.

Barksdale Valve, the current supplier, agreed to manufacture 10 redesigned valves for testing and evaluation. Because of the close relationship in cost, it was determined to drop the rework kit and procedure and procure only complete valve units. Implementing the rework procedure would void the warranty also, unless Barksdale performed the labor, making it a less desirable alternative.

The redesigned valves (fig. 9) were installed on the PIP howitzer SN 309 and subjected to extensive environmental effects during a sequence of assorted abusive maneuvers over various terrains, including fording through water and towing through swamp conditions. The valves were also tested in the environmental chamber to monitor their effectiveness at extreme temperatures (-40°F to +145°F).

All tests were passed successfully and the new Barksdale valve was approved.

To avoid a sole supplier situation, a second source was obtained. Teledyne offered a nearly identical valve that contained a 400 series, stainless steel shaft. However, instead of using a press-fit bronze bushing, their design allows hydraulic fluid to lubricate the shaft up through the cast housing shaft bore. The fluid is contained by an O-ring that is mounted onto the shaft. The constant lubrication, along with the corrosion resistance of the shaft material, is considered suitable to eliminate the chance of seizing. The Teledyne valve was accepted as a second source.

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<sup>1</sup>FY 88 dollars.

Both valves will now be available for implementation into the system by way of attrition.

## **MANUAL HYDRAULIC PUMPS**

Failure repeatedly has occurred on the pump housing of the hydraulic pump at the pin joint. The pump bodies fail because of overloading in the direction perpendicular to rotational movement at the pivot pin joint. The functional requirements of the existing pump are governed by document MIL-P-5515<sup>2</sup>. This document was originally written for back-up hand pumps used in aircraft hydraulic systems. Frequent use and occasional abuse or misuse will cause the current aluminum body pump to fail.

Bending moment stress analysis, applied at the area of reoccurring failure on the pump body, determined that the minimum strength of the pump body should be 90 ksi to meet the 160 lb side load requirement of MIL-P-5515. Existing pumps fail because they have been manufactured from cast aluminum of strength less than the required minimum yield strength and will break due to fatigue failure. Except for intentional abuse or misuse, manufacturing the pump bodies from alloy steel of 90 ksi minimum yield will prevent pump failure.

With the addition of the strength and material requirement for the body of the hydraulic pump, the pump body will continue to meet all existing dimensional and functional drawing requirements. Dimensional requirements are met through specification AN6248-3<sup>3</sup>. Functional requirements are met through specification MIL-P-5515. Lastly, the pivot point is dimensionally located on the pump drawing (fig. 10).

By strengthening the pump body, failure is eliminated. The resulting effect will be reduced maintenance and reduced howitzer downtime.

The pumps will be fielded through attrition; therefore, they will be replaced as needed. Since the new pumps (fig. 11) will have the same configuration as the existing pumps, they are easy to retrofit and are a direct replacement item.

<sup>2</sup>MIL-P-5515, Pump, Hydraulic, RAM, Hand Driven, Air Force-71, 17 May 1972.

<sup>3</sup>AN6248-3, Pump, Hydraulic Hand, Type 3000, Air Force-99, 1 May 1973.

## AXLE BUSHING LUBRICATION

Lack of lubrication in areas between the axle shaft and the cylindrical bushing caused the bushing to wear, which at times created a loud popping noise while raising and lowering the wheels. Currently, the axle bushing assembly is lubricated with grease at two external ports that are located on the top of the stationary bushing. Lubrication is necessary to allow ease of axle rotation with respect to the stationary bushing; the axle remains stationary with respect to the bushing except to raise and lower the wheels for emplacement and displacement of the howitzer.

To provide thorough lubrication, several concepts were considered. An internal grease port assembly or spider assembly located within the axle was considered. Conceptually this was determined unacceptable because of projected installation and welding difficulty associated with manufacturing, and because of possible fatigue failure during transit. Secondly, a permanent, self-lubricated material was considered because it can provide uniform lubrication over the whole bushing surface area; this concept was tested and accepted.

Several self-lubricated materials were considered but not accepted. A molybdenum disulfide solid lubricant was not selected because it is coated by the method of spraying or dipping, and because the thin layer of coating must be refurbished every several years. An electroless nickel/polymer composite plating was not selected because the friction between the plated bushing and steel axle was greater than the current grease-lubricated axle/bushing assembly.

A hardened electroless nickel plating infused with polymers was pursued. This process provides maximum uniformity of plating thickness and allows the plating to become an integral part of the top layers of the base metal. In addition, the friction between the plated bushing and steel axle is less than the current grease-lubricated assembly. The material tested and accepted was NEDOX-SF2, of General Magnaplate Corp., Linden, New Jersey. The final design included plating the manganese bronze bushing and retaining usage of existing grease ports for additional lubricity and increased life.

The essential requirement for the axle bushing assembly is that the wheel assembly can be raised and lowered by activating the hydraulic pumps. Plating requirements include the following:

- Electroless nickel alloy plating infused with Teflon or fluorocarbons
- Resultant hardness strength of Rockwell C50-65
- Minimum operating temperature range of -45°F to 400°F
- Surface plating thickness of  $0.0010 \pm 0.0002$

Advantages of General Magnaplate Corporation, Linden, NY (NEDOX-SF2) over present system include:

- A uniformly coated surface is provided by electroless process; whereas, existing grease lubrication provides unevenly lubricated surface
- Corrosion protection is provided by nickel alloy of the electroless plating
- Wear resistance is provided by Rockwell C50-65 plating hardness
- Coefficient of friction is 0.06. In comparison, the present lubricated system is 0.17
- Operating temperature range exceeds the -45°F to 145°F military requirement.

### **TRAVERSING ANGLE DRIVE FAILURES**

When the carriage is on the base plate, and the wheel assembly is in its partially up position, it is presently possible to damage the traversing angle drive housing. While traversing the gun tube, the traversing angle drive unit, which is exposed through the bottom of the top carriage, can strike the end cap of the actuator cylinder of the bottom carriage assembly. Repeated damage resulting from this interference causes failure to the bottom of many traversing unit housings.

Interference can be eliminated by shimming the angle drive unit. The maximum interference between the housing of the angle drive unit and end actuator assembly was determined to be 0.49 in. Therefore, the interference between the angle drive unit and actuator arm will be eliminated by shimming the angle drive unit to 0.50 in.

Shimming the angle drive unit results in a 0.50-inch reduction of engagement between the pinion gear of the angle drive unit and the ring gear of the bottom carriage. Failure of the pinion and ring gear should not occur as the remaining 1 1/2 in. tooth engagement assures a safety factor exceeding two.

### **TRAVERSE LOCKING ASSEMBLY**

A self-contained, traverse locking device was considered to eliminate cables, links, and chains of the current design. A self-contained, semiautomatic, locking assembly was developed (fig. 12). The essential requirement is that the locking assembly locks the top and bottom carriage together during towing procedures.

The advantages over the present system include:

- Reduced maintenance due to elimination of damaged hydraulic lines resulting from interference between the hydraulic lines and the present key and cable assembly.
- Reduced operator effort provided by the semiautomatic feature (fig. 13).

### **TRAIL LOCKING ASSEMBLY**

The addition of a secondary safety latch was required to restrict the primary trail locking handle from opening during transit; if not adjusted properly, the existing locking handle can rotate open during transit and possibly cause a fatal accident by spreading the trail legs. A spring loaded trail locking handle assembly (fig. 14) was designed to retain the primary locking handle. This secondary latch has an open and closed position for ease of operation.

Initially, to accept the pin of the secondary latch, a square bracket with a slot was welded onto the existing locking handle. This bracket performed the proper function of retaining the pin of the secondary latch and preventing the existing locking handle from rotating open. To perform the same function, a simplified bracket was developed. The final bracket consisted of a flat plate which is to be welded to the existing locking handle.

The essential design requirement was to restrict the trails from opening during transit. Desired features of the trail locking assembly were that it be self-contained and have positive open and closed positions. The advantage over the present system is that it improves safety by eliminating possible chance of the trails spreading during towing operations.

### **BASE PLATE LOCKING ASSEMBLY**

The previous problem experienced with the base plate locking assembly involved the loss of the blocks on the base plate which house the locking pin during firing operations. The blocks were susceptible to damage during stowage of the base plate onto the trails before towing of the weapon. Without the blocks, the base plate cannot be locked to the weapon and the weapon is then considered down for safety reasons.

Two designs were considered as solutions to the base plate locking problem. The first concept included a spring-loaded ring which would be attached to the existing handle and would mesh with the ring fixed to the bottom carriage. This design was not incorporated onto the system because of its mechanical complexity and susceptibility

to environmental failure. The design that was adopted includes a modified handle (fig. 15) with a block attached and a tube welded into the base plate. This design allows the carriage and the base plate to be connected by pinning through the handle/block assembly and then through the tube in the base plate. This design is a simple but effective way to eliminate the problem (fig. 16).

The incorporated locking device will reduce downtime because of the elimination of the blocks from the surface of the base plate. Maintenance should also be reduced for the same reasons. This system is inexpensive and adds no significant weight to the system.

### **EQUILIBRATOR/RECUPERATOR VALVE**

Due to continued problems experienced in the retention of nitrogen in the equilibrator and recuperator assemblies, it was determined that the nitrogen charging valve (MS28889) was not of sufficient quality to resist failure after repeated cycling. Resulting failure caused by nitrogen leakage includes increased elevation hand wheel effort and recoil failures. The newly adopted valve (HF2001) was developed by Hydro Fitting Manufacturing Corporation. This new valve will replace the presently used MS28889 valve.

The HF2001 valve provides improved durability, reliability, and a reduction in maintenance required when compared with the standard valve. Another positive factor in the choice of this valve was the fact that it fit within the dimensional envelope of the existing MS28889 valve. This will allow for a one-to-one substitution. The improved valve design boosted the pressure rating from 5,000 to 10,000 psi, and increased the life expectancy from 10 to 15 open/close cycles to 500 or more cycles. The new valve design substituted a double O-ring seal for the traditional metal-to-metal seal used in the standard MS28889 valve.

The new design not only improved the valve's operating characteristics but also eliminated problems experienced with sealing of the standard valve because of overtorquing of the metal-to-metal seal. In the standard valve design, a groove was formed in the metal-to-metal valve seat during manufacturing by applying a 125 in.-lb load. This form of sealing is effective initially, but after repeated cycling the groove would be cut deeper into the valve seat and the seal would begin to leak. The metal surfaces of the valve seat are also susceptible to fluid-flow erosion, which made the high pressure valve further prone to leakage. In the HF2001 design, the double ethylene-propylene O-rings form the high pressure seal, which will vastly improve the valve's life expectancy (fig. 17).

The improved valve passed all temperature (-45°F to 145°F) and cycling (500+ cycles) tests at Rock Island Arsenal (RIA), Letterkenny Army Depot (LEAD), and Aberdeen Proving Ground (APG).



## EQUILIBRATOR BELLOWS

The bellows function is to cover and protect the machined surface of the equilibrator rod. When the gun tube is elevated or depressed, the bellows retracts or extends in a cyclic fashion. Concern was expressed because of the bellows failure to protect the piston rod. Failure of the bellows allows moisture to accumulate around the piston rod, initiating corrosion.

The existing bellows is made of an ethylene-propylene or equivalent material. This selection was based on the following criteria:

- Temperature range: -65°F to 130°F.
- Estimated life: 50,000 full stroke (25 in.) cycles
- Resistance: Must be resistant to oil and ozone
- Construction: Molded or sewn construction is acceptable
- Maximum extension: 27.2 in.
- Minimum extension: 2.25 in.

In conversations with personnel from RIA who investigated bellows failures experienced at Ft Bragg, North Carolina, it was noted that failures ranged from tearing of the bellows (this could occur from normal use or during scheduled maintenance) to stitch deterioration of the nylon thread used in the bellows sewn construction.

In an effort to eliminate bellows failures that were causing the equilibrator piston rod to corrode, two different modified designs were considered. The first new design incorporated a zipper and a stronger material; the second design considered was a one-piece, molded construction version made with a stronger material.

The main reason for looking into a design which incorporates a zipper and a stronger material is the obvious maintenance benefits it would render. A zipper version bellows would allow the changing of this item to be done by organizational maintenance instead of the direct support maintenance group, and allow ease of installation without disconnecting the equilibrator assembly and bleeding off the nitrogen. This change would significantly improve unit readiness. Even with these benefits, it was decided that the zipper version bellows was not the most effective way to solve the problem. The following reasons help to support this decision.

- Multiple failure modes
  - Stitch construction
  - Binding zipper
  - Deterioration of zipper stitching
  - Possibility of zipper being left partially or fully open
  - Zipper could separate during normal usage

- Must use sewn construction

Possible for water seepage through stitching

- Less durable over time

Zipper-type protective covers are not intended to be used for cyclic-type applications.

- Costly

Zipper adds \$15-\$20

If stitching is coated to help prevent leakage, this can be done for an additional cost

Additional QA inspection will be required

- Not easy to open and close

The second bellows considered was of a one-piece, molded construction. The new material used is a 0.033 neoprene-coated nylon. The attractive attribute of this type of bellows is its durability. Its excellent resistance to abrasion and tearing is superior to the bellows existing material. The one-piece construction lends itself to very limited modes of failure because it lacks any stitching or zippers which could cause more problems. The cost of the molded version bellows is comparable to the existing bellows, after the initial tooling set-up. Based on this information, it was felt that a one-piece, molded version bellows would best fit the weapon's needs. The stronger material will increase durability and, in turn, decrease maintenance needed for the part (fig. 18).

## **U-JOINT COVERS**

The traversing shaft assembly that is located under the access covers on the top carriage has experienced corrosion problems that are documented in numerous system performance feedback reports which address problem areas on the M198. U-joints 12008201 and 12008203 tend to cause one of two problems:

1. If proper maintenance is not performed, the u-joints in question will lose lubrication and oxidation will begin to form. Corrosion of the joints seems to be fairly common and replacement occurs frequently.

2. If proper maintenance is performed on the assembly, the wide temperature range (WTR) grease applied to the U-joints tends to get on the friction faces of the torque limiter. Grease on the torque limiter eliminates its effectiveness by allowing unwanted slippage.

In an effort to eliminate both corrosion of the joints and the inadvertent lubrication of the friction faces of the torque limiter during quarterly maintenance, a protective U-joint cover (fig. 19) was designed to keep the U-joints lubricated at all times while keeping the WTR grease contained.

The U-joint covers are of a bellows construction, much like that of the equilibrator bellows. The covers should aid in the effort to reduce corrosion-related failures, as well as the noncorrosion problems encountered. The covers should significantly reduce maintenance needed for the assembly, and no weight penalty will be encountered. The cost of the covers is small compared to the reduction in failures and maintenance which will be encountered.

### **SKID PLATES**

Currently, the spade bracket blocks located at the end of each trail and the eye bolts located underneath each trail can be damaged and/or lost due to impact. To protect the spade bracket blocks and eye bolts from impact, plates were added to the trails. These plates provide protection from impact during shipment while loading and unloading the howitzer off ramps. Maintenance reduction, system safety improvements during airlift, and component durability improvements are some of the benefits resulting from the addition of the protective plates.

### **GASKET MATERIAL**

The existing gasket material used on the M198 howitzer for the following gaskets was deemed unacceptable for its intended usage:

<u>Drawing Number</u>	<u>Quantity</u>
12007797	1
12007978	4
12007999	2
12008085	2
12008094	1
12008095	1
12008192	2
12008202	1
12008328	2
12008457	1
12008741	2

<u>Drawing Number</u>	<u>Quantity</u>
12008771	4
12008773	3
12008775	1
12008825	1
12008826	1
12008991	1
12009011	2

In many cases, the gaskets on this list would deteriorate and not be able to perform their sealing function. On parts where the gaskets are removed repeatedly for access to other weapon assemblies, the gaskets would tend to separate and break prematurely. The gasket material used during early howitzer testing was supplied by Armstrong and its part number was ACCOPAC CN-888. This material was tried and accepted by the user. An Armstrong representative revealed upon inquiry that the material initially tested was no longer supplied. This inquiry took place in 1984 when it was noticed that the gaskets used for the access covers (12008273) on the top carriage were failing on a regular basis. It was pointed out that the material listed on the cover drawing at the time (MIL-C-6183, cork and rubber composition) was of an inferior quality. The tensile strength of the material initially tested was 800 psi, while the strength of the material called for on the cover drawing was 300 psi. In an effort to upgrade the material, Armstrong recommended Armstrong CN-705, whose industry standard equivalent is ASTM F104, SPEC F 3371 76 M3.

This material change was made in an effort to raise the quality of the gasket to the level at which it was when the weapon was initially tested. The new material was adopted for all gaskets listed above. Changing the material should not result in a significant cost increase, while corrosion problems related to the failures of the gaskets should be largely reduced.

### **SPADE RETENTION**

A spade retention device was requested by the user to prevent the spades from coming out of their trail brackets during severe transit operations. Currently, straps with buckles are used; however, they tend to fray and become loose during transit. Two alternatives were considered, namely, a spring-loaded latching device and straps with attaching carabiner clasps.

The spring-loaded latching device was tested, but was not accepted because of alignment problems. For each of the two spades, the spring-loaded latching device was to replace one of the side brackets located on the trail and a hole was to be machined into each spade. Functional-related problems experienced during testing led to nonacceptance of this alternative. Misalignment of the latching device pin and the spade hole due to the weight of the spades and angle of the spade when placed into the trail bracket assembly made this alternative impossible to implement.

Fabric straps with sewn loops and locking carabiner clasps were also tested, but not accepted. Problems associated with this method include: the loss of carabiners because of pilferage and metallic freezing of the carabiner in locked position due to the environment. This binding was not considered to be major since the carabiner is meant to be semipermanent and would only need to be removed in the event that either the carabiner or the strap required replacement.

Since neither of the two alternative spade retention methods were accepted, the current spade retention with use of straps and buckles remains unchanged.

### **STRAP RELIABILITY PROGRAM**

Straps with buckles are used to retain several howitzer components. Strap buckles tend to loosen and come undone. The buckles, straps, and even the items they secure, are lost. This can be prevented by providing a more positive restraint than what exists.

The solution was to cut the straps to specific lengths and use locking carabiners to replace the buckles. The carabiners were chosen because they are larger in size, which makes them easy to handle, and are extremely durable.

Other mechanisms were looked at, but most were plagued with the same problems that affected the strap buckles. Most would never survive the environment they would have to be used in.

The carabiners proved their worthiness during testing, but were removed from the PIP because of the fear of pilferage. Therefore, the current strap buckle assemblies remained unchanged.

### **SPADE KEY RETENTION BRACKET**

The spade keys are not positively secured in their retaining basket. Unrestrained keys pop out of their baskets during severe towing vibration. Without spade keys, the howitzer cannot be fired. A spade key retention assembly was developed to restrain the keys during nonfiring operations (fig. 20).

The retainer is a screw-type, clamping mechanism. It accomplishes its task without the use of cables, links, and chains. Cables, links, and chains are prone to breakage. The retainer is designed with a special thread form to help prevent vibration loosening and its design helps it survive user abuse.

The advantages of incorporating a spade key retention system include: prevention of the loss of the spade keys, reduction in howitzer downtime and maintenance, and reduction in the cost of replacing lost keys.

## **TRAIL LOCKING PIN LINKAGE ASSEMBLY**

The trail locking pins (fig. 21) are being damaged by having the trails dropped on them. This pin works in tandem with the trail clamp to keep the trails together in case the clamp accidentally releases. A safety hazard exists if this pin is missing or damaged to the point of being unusable.

To help prevent damage to the pin, its connecting cable was shortened from 8 to 4 in. This keeps the pin from going underneath the trail and getting smashed. In addition, a housing was made to store the pin when not in use. When in this housing, the pin cannot get in the way of anything that can cause it damage.

Mechanical devices were considered, but none were found adequate. Some of the problems associated with the devices were: too little space existed to locate and operate a device, it would have to operate in an extremely dirty environment, and there was a need for alignment between the trail pin holes in both trails.

The major advantage of these improvements is the reduction in the amount of pins lost and damaged at a weight penalty of a few oz./howitzer.

## **SPADE KEY LOCKING PIN LINKAGE ASSEMBLY**

The spade key locking pins are being damaged by having the trail legs dropped on them. They are also being lost by the cables getting snagged in brush during towing. The pins lock the spade keys in place. The howitzer cannot use the spades if these pins are missing or damaged.

To help eliminate cable damage or pin lose, the retaining cable was shortened from 12 to 8 in. and a housing was designed for pin storage. The cable abridgement eliminated the deformation problem resulting from dropping the trails and reduces the likelihood of snagging from bushes during towing. The housing provides a positive storage area further reducing the likelihood of damage or loss.

Mechanical devices were considered, but none were found to do the job. Some of the problems associated with the devices were: too little space existed to locate and operate a device, it would have to operate in an extremely dirty environment, and therefore be susceptible to binding.

The advantage of these improvements is the reduction in the amount of pins lost and damaged, at a weight penalty of a few ounces per howitzer.

## **AIRLIFT EYE BOLT RETENTION ASSEMBLY**

The airlift eye bolt is unrestrained during nonairlift maneuvers. An unrestrained eye bolt creates a lot of noise by banging against the trail leg and, in the process, wears down the leg's paint finish. The airlift eye bolt retainer (fig. 22) solves these problems by restraining the eye bolt during nonairlift maneuvers.

The retainer is a screw-type, clamping mechanism. It accomplishes its task without the use of cables, links, and chains which are prone to breakage. The retainer is designed with a special thread form to help prevent vibration loosening and its low profile design helps it survive user abuse.

The requirement of no cables, links, and chains eliminated a lot of candidates for the job. Some other devices that were considered and rejected were welding/machining clamps and spring clips. The clamps would be extremely difficult to CARC paint due to their fine linkages. The spring clips are used with the upper carriage's eye bolts, but were deemed incapable of surviving the user abuse in the trail leg area.

Advantages of incorporating an eye bolt retainer are improved operations and reduced maintenance at a negligible penalty of less than 2 lb/howitzer.

## **SWING HANDLE**

The swing handle (fig. 23) was proposed as an alternative for extending the trail handholds to provide more room for additional manpower to emplace the howitzer trails. These handles would allow one more man to lift each side per trail. This handle can be positioned to provide the most leverage or additional lift, and can be folded against the trail when not in use. Advantages include the following:

- Body of the assembly is welded directly to the trail, which is aluminum alloy
- Handle is steel bar and is strong enough to support a 275 lb. static load
- The whole assembly weighs less than 10 lb
- Up to four units can be attached if room is available fore and aft of the existing trail handholds. Two aft of the existing handholds will meet present requirements and provide the most leverage and mechanical advantage.

During towing tests with the howitzer attached to the prime mover, the driver jackknifed the vehicle into the howitzer trail while backing up. Since the swing handle protrudes a distance from the trail, deformation of the handle did occur. The final design proved to be of sufficient strength to withstand direct impact and continue to function as designed.

### **STANDOFF**

The standoff (fig. 24) was designed to prevent the brake line hose from being pinched between the bottom carriage and the trail. Its function is to position the bow of the hose away from the corner by guiding the hose through a loop in the assembly.

This design is a simple, 1/4 x 3 1/2 x 4 in., aluminum alloy block with a double chamfered edge, two 1 1/4 in. holes and a 3/8 in. diameter guide loop with about a 1 1/2 in. opening between the loop and body. The block is welded to the trail with the 3 1/2 in. dimension perpendicular to the side of the trail.

Due to the relative simplicity of the standoff and ease of manufacture, this design was selected.

### **LUNETTE EXTENSION**

A lunette extension was an alternative solution to muzzle brake removal when loading and unloading the M198 from the C-130 cargo plane. Since the muzzle brake is considered indispensable for firing missions, the lunette extension was the preferred method of modifying the howitzer for air cargo transport. The feasibility of providing a permanent extension without major structural changes to the M198 were not considered economical because of major trail redesign, so a temporary design was pursued. Durability was considered critical given that the lunette may be abused and used for towing other than low velocity maneuvers at airstrips.

Various designs of aluminum and steel were tested. The tests indicated that the failure-prone area was around the pin hole of the lunette insert that attaches into the trail leg end. Substantial weight reductions were realized when the critically loaded area was determined to exist only at the insert end. Using webs to reduce bending loads at this junction extended the towing distance to failure well beyond the 3-km requirement. Computer aided design analysis of the final design resulted in an 18% increase in durability and a 62% drop in weight from 250 lb to 95 lb. This item was not proposed as part of the final PIP package because of the user's desire for a follow-up study on a permanent lunette extension.



The first prototype tested was an aluminum structure with a captured steel insert. Welded structural members include the base plate, insert, receptacle and inner/outer ribs. Completing the structure is the pin web assembly and the steel insert, which is pinned to the howitzer. Failure occurred during 2 and 6 in. washboard test runs. Although washboard tests were not a requirement, these tests were used to determine durability.

In an effort to reduce weight problems associated with inconsistent welding techniques and reduce manufacturing costs, a bolted aluminum-steel hybrid was designed and tested. Failures occurred during static tests.

A third aluminum design proved to be more successful. Failure did not occur at the weld as expected, but at the rear pin hole. This failure was attributed to improper assembly, allowing the straight pin of the web to loosen and thus result in an increase in bending loads. Failure occurred during the fourth test despite corrections made to manufacturing and assembly techniques. Loads were highest at the rear pin hole where the cross-sectional area is the smallest. This hole was eliminated in follow-up designs.

On the sixth and final attempt, failure occurred on the Belgian block course after 500 miles of continuous towing, which greatly exceeded the 3 km cross-country requirement. Although the design intent was merely to maneuver the howitzer on and off the C-130 in stowed configuration, the fear was that the user would leave the extension permanently attached. Since engineering could not guarantee a permanent solution without increasing the cross-sectional area at the front pin hole which requires a major redesign of the trail assembly this design was not accepted for implementation.

## **PARKING BRAKE ADJUSTMENT PROCEDURE**

The parking brake adjustment procedure was adopted as a result of cases of brake failure caused by maladjusted brake pads. The amount of holding power required and how it is related to specific values of adjusting rod tension first had to be determined. This was then correlated to the maximum incline a given torque can restrain a howitzer.

Positive indicators for parking brake engagement were considered to alert the towing crew that the brakes were set and ought to be released before towing. Various proposals were rejected for logistical reasons, and an adjustment procedure seemed the most viable alternative.

In normal use, brake pad wear is minimal in daily operations, with the major factor being compression set of the brake pad material. Since adjustment is done during initial installation of the brake assembly, any towing with the brakes engaged will alter this setting, requiring readjustment due to the worn condition of the brake pads.

Since no adjustment procedure exists, improper adjustment during assembly is likely. This results in failure to restrain the howitzer on sloping terrain, worn brake pads, and bent adjustment rods. A properly adjusted brake requires a 40 ft-lb force at the end of the brake handle to lock the system. With the pads touching the rotor, the handle will be located at a 40-deg angle.

The procedure chosen provides initial measurements for the individual linkages. The system is then fine tuned by adjusting the linkages further until the handle is at a 40-degree angle, as determined with the gunners quadrant and with brake pads resting against the rotor. This procedure provides the locking power to restrain the M198 howitzer on a 25% incline and only requires a 40 ft-lb locking force.

## **CONCLUSIONS**

The U.S. Army Armament, Munitions and Chemical Command Configuration Control Board conducted a level 1 meeting 88-20 on 8 September 1988. As a result all recommended improvements were accepted for production. These improvements as discussed in this report are contained in the engineering change proposal 68A2066. Watervliet Arsenal was selected as the manufacturer of these improvements.

Table 1. Equilibrator adjusting screw test data (original components)

	M198 HOWITZER SN 309 - PIP TEST DATA			
	EQUILIBRATOR ADJUSTING SCREW			
		(LETTERKENNY)		
BOTH SIDES :				
Original Components				
Initial Readings				
		LEFT SIDE		RIGHT SIDE
DIRECTION OF LOAD MOVEMENT	POINTER POSITION	TORQUE VALUES (FT-LBS)		TORQUE VALUES (FT-LBS)
		1250 PSI		1250 PSI
		MAX QE (+1200 mils)		MAX QE (+1200 mils)
FROM CENTER > UP		115		120
FROM CENTER > DOWN		250		245
FROM +5 > DOWN		<250		<250
FROM -5 > UP		105		120
		1450 PSI		1450 PSI
		(+600 mils)		(+600 mils)
FROM CENTER > UP		30		35
FROM CENTER > DOWN		115		130
FROM +5 > DOWN		95		90
FROM -5 > UP		30		75
		1650 PSI		1650 PSI
		TRAVEL LOCK (+250 mils)		TRAVEL LOCK (+250 mils)
FROM CENTER > UP		75		105
FROM CENTER > DOWN		23		70
FROM +5 > DOWN		40		35
FROM -5 > UP		55		115
		1950 PSI		1950 PSI
		MIN QE (-71 mils)		MIN QE (-71 mils)
FROM CENTER > UP		145		145
FROM CENTER > DOWN		55		50
FROM +5 > DOWN		92		65
FROM -5 > UP		133		150

Table 2. Equilibrator adjusting screw test data (PIP components)

	<b>M198 HOWITZER SN 309 - PIP TEST DATA</b>		
	<b>EQUILIBRATOR ADJUSTING SCREW</b>		
	<b>(LETTERKENNY)</b>		
<b>BOTH SIDES :</b>			
Components from ARDEC			
Test assy 4 (right side)			
New steel			
1.25 In screw (coated)			
w/bearing,old slide brkt,			
bored cover,uncoated guides			
		<b>LEFT SIDE</b>	<b>RIGHT SIDE</b>
<b>DIRECTION OF</b>	<b>POINTER</b>	<b>TORQUE VALUES</b>	<b>TORQUE VALUES</b>
<b>LOAD MOVEMENT</b>	<b>POSITION</b>	<b>(FT-LBS)</b>	<b>(FT-LBS)</b>
		1250 psi	1250 psi
		MAX QE (+1200 mils)	MAX QE (+1200 mils)
FROM CENTER > UP		28	48
FROM CENTER > DOWN		105	135
FROM +5 > DOWN		90	125
FROM -5 > UP		38	50
		1450 psi	PSI
		(+600 mils)	(+600 mils)
FROM CENTER > UP		15	12
FROM CENTER > DOWN		44	60
FROM +5 > DOWN		33	50
FROM -5 > UP		13	17
		1650 psi	1650 psi
		TRAVEL LOCK (+250 mils)	TRAVEL LOCK (+250 mils)
FROM CENTER > UP		45	46
FROM CENTER > DOWN		1	1
FROM +5 > DOWN		4	7
FROM -5 > UP		45	42
		1960 psi	1980 psi
		MIN QE (-71 mils)	MIN QE (-71 mils)
FROM CENTER > UP		120	120
FROM CENTER > DOWN		32	40
FROM +5 > DOWN		43	46
FROM -5 > UP		110	107

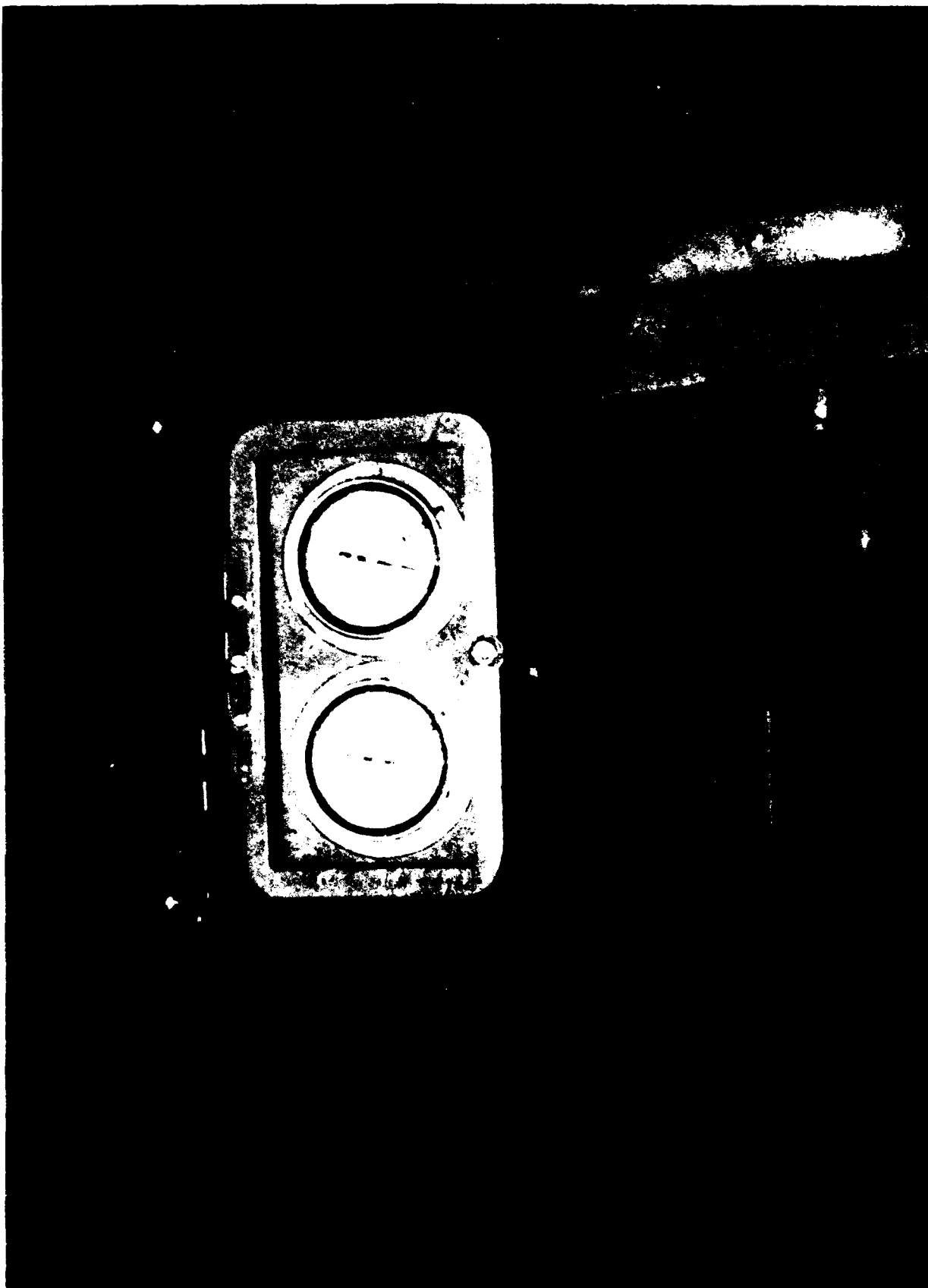


Figure 1. Brake precheck gauges

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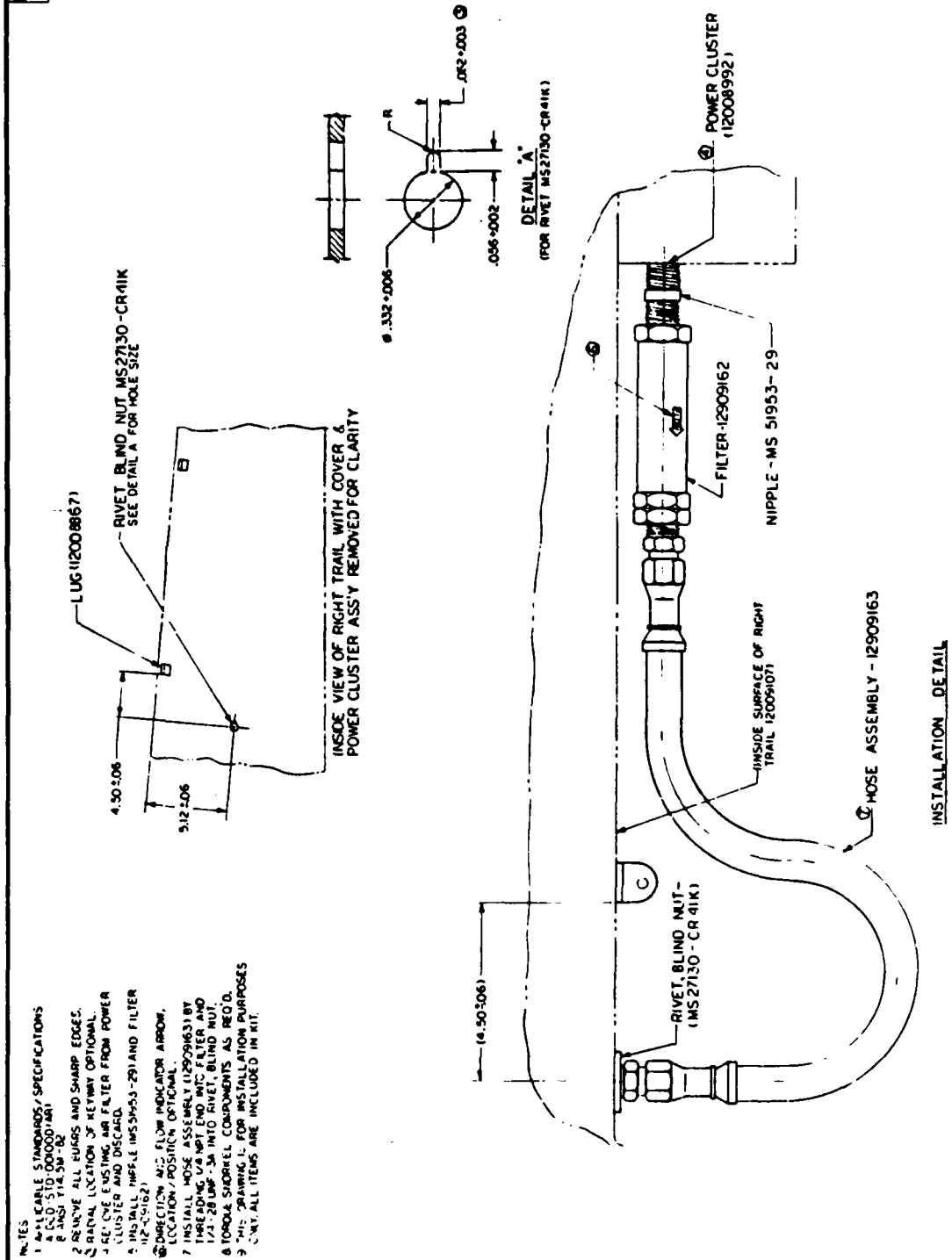


Figure 2. Snorkel system

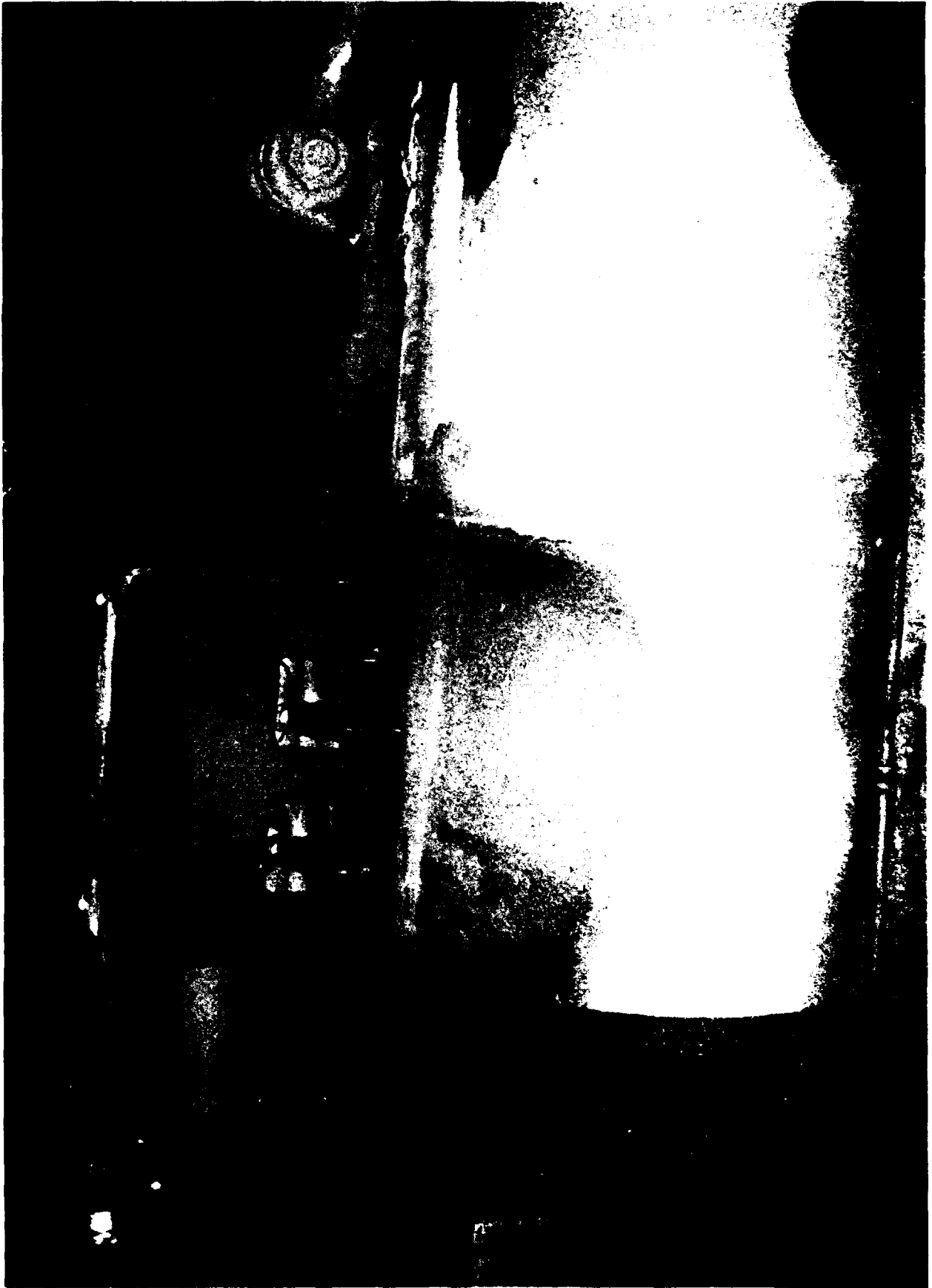


Figure 3. Brake cover extension

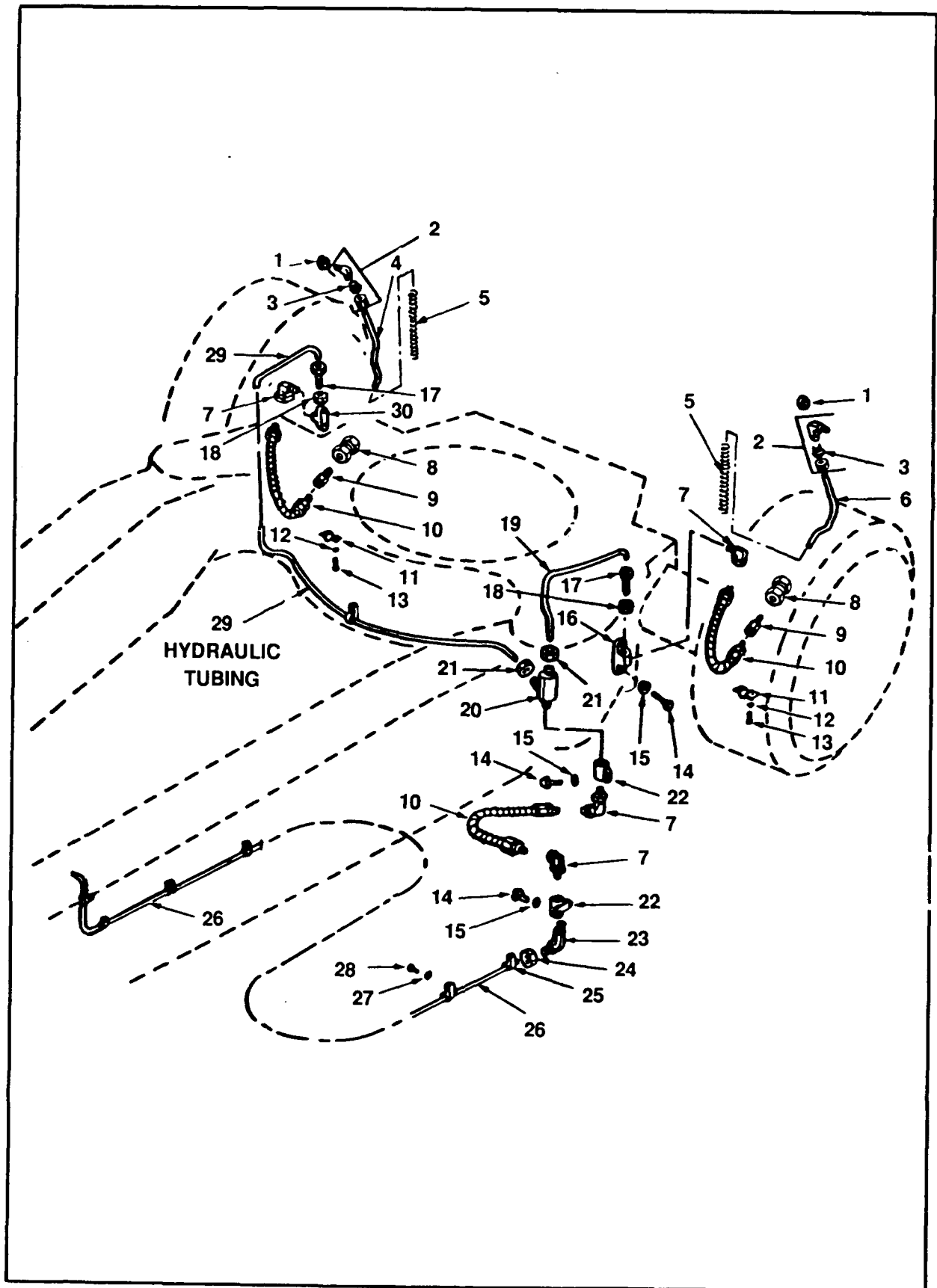


Figure 4. Hydraulic brake line tubing



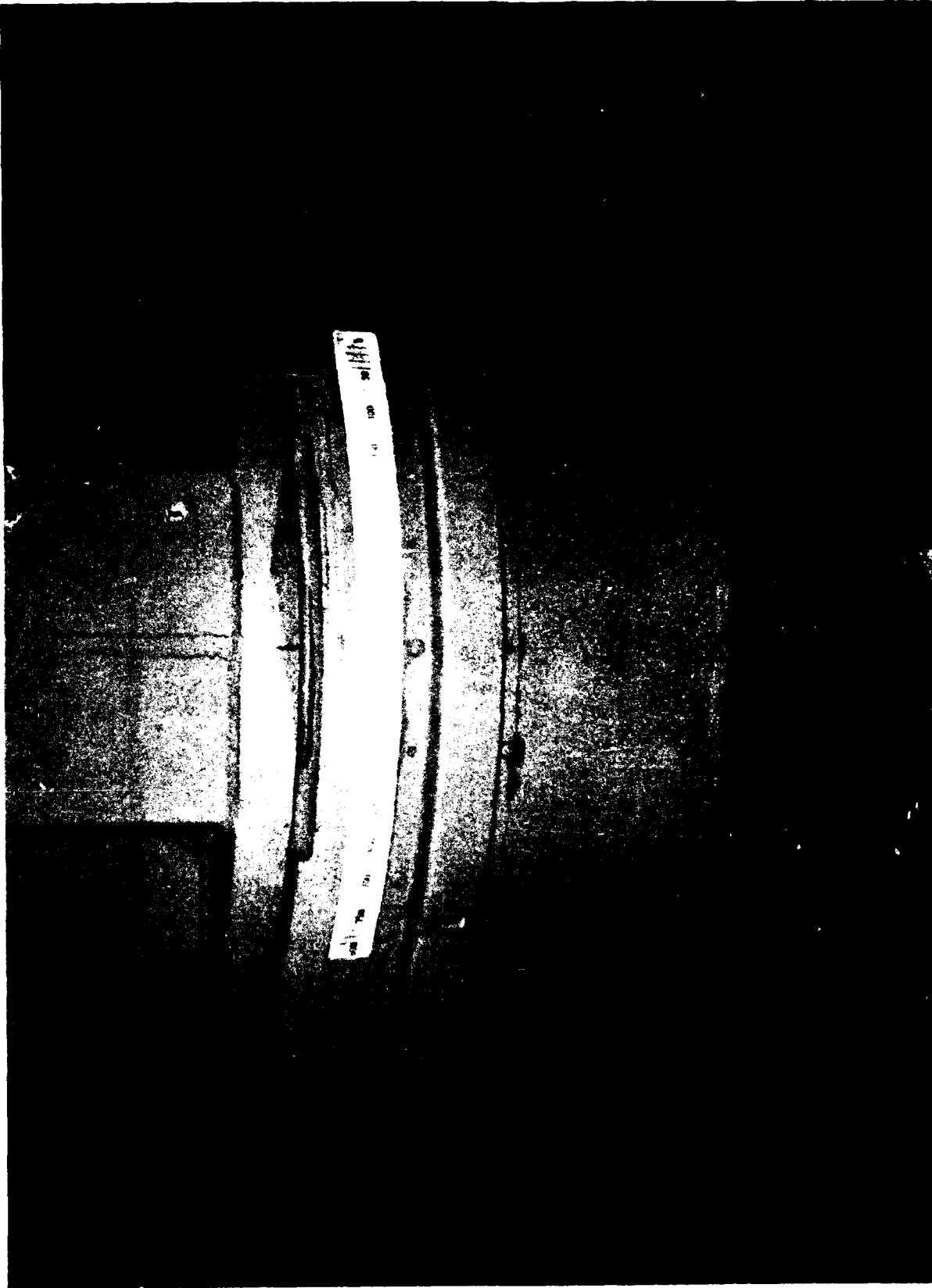


Figure 5. Brake line covers

REV	DESCRIPTION	DATE	APPROVED
A	REDRAWN WITH CHANGE	8/9/88	L. A. J.
B	FOR 2023. 8300	9/27/87	J. A.
C	FOR 2023. 90-03-23	9/27/87	J. A.
D	FOR 2023. 90-03-23	9/27/87	J. A.

NOTES:  
1- APPLICABLE STANDARDS/SPECIFICATIONS  
A- DOD-STD-00100 (DIAR)  
B- ANSI Y14.5-1982

## 2- REQUIREMENTS:

- A) MATERIAL:  
1- BODY: BRASS (C28300 OR C37700)  
2- HANDLE: ALUMINUM 6061-T6 OR 2024-T4  
B) TEMP RANGE (OPERATING): -45° TO 145°F  
C) PRESSURE RANGE (OPERATING): 0-150 PSIG MIN.  
D) THREAD SIZE: 1/4-18 NPTF  
E) ORIFICE DIA: .125 DIA TO .170 DIA  
F) IN CLOSED POSITION VALVE MUST WITHSTAND 200 PSIG HYDROSTATIC PRESSURE FOR 30 SECONDS, MAXIMUM ALLOWABLE LEAKAGE .1 SCC/MIN  
3- DIMENSIONS SHOWN ARE FOR REFERENCE ONLY.  
4- PROTECTIVE FINISH: FINISH 20.24 OF MIL-STD-171. DO NOT PAINT THREADS, ORIFICES OR MOVING PARTS.  
5- ITEM IDENTIFICATION: APPLY THE FOLLOWING MARKING TO CONTAINER IN ACCORDANCE WITH MIL-STD-130:  
19200-12909068

MFR- [MANUFACTURER'S]  
CAGE CODE PART NO

6- IDENTIFICATION OF THE SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM

## 7- SUGGESTED SOURCES OF SUPPLY:

TELEDYNE REPUBLIC  
15655 BROOKPARK RD  
CLEVELAND, OHIO 44142  
PART NO: 1-1089-5  
CAGE CODE:  
WHITEY CO.  
318-T BISHOP RD  
CLEVELAND, OHIO 44143  
PART NO: B-1GM4-A-BK8-LT  
CAGE CODE:

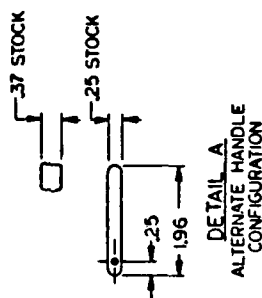
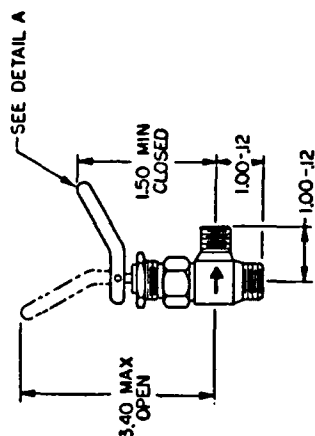


Figure 6. Toggle valve

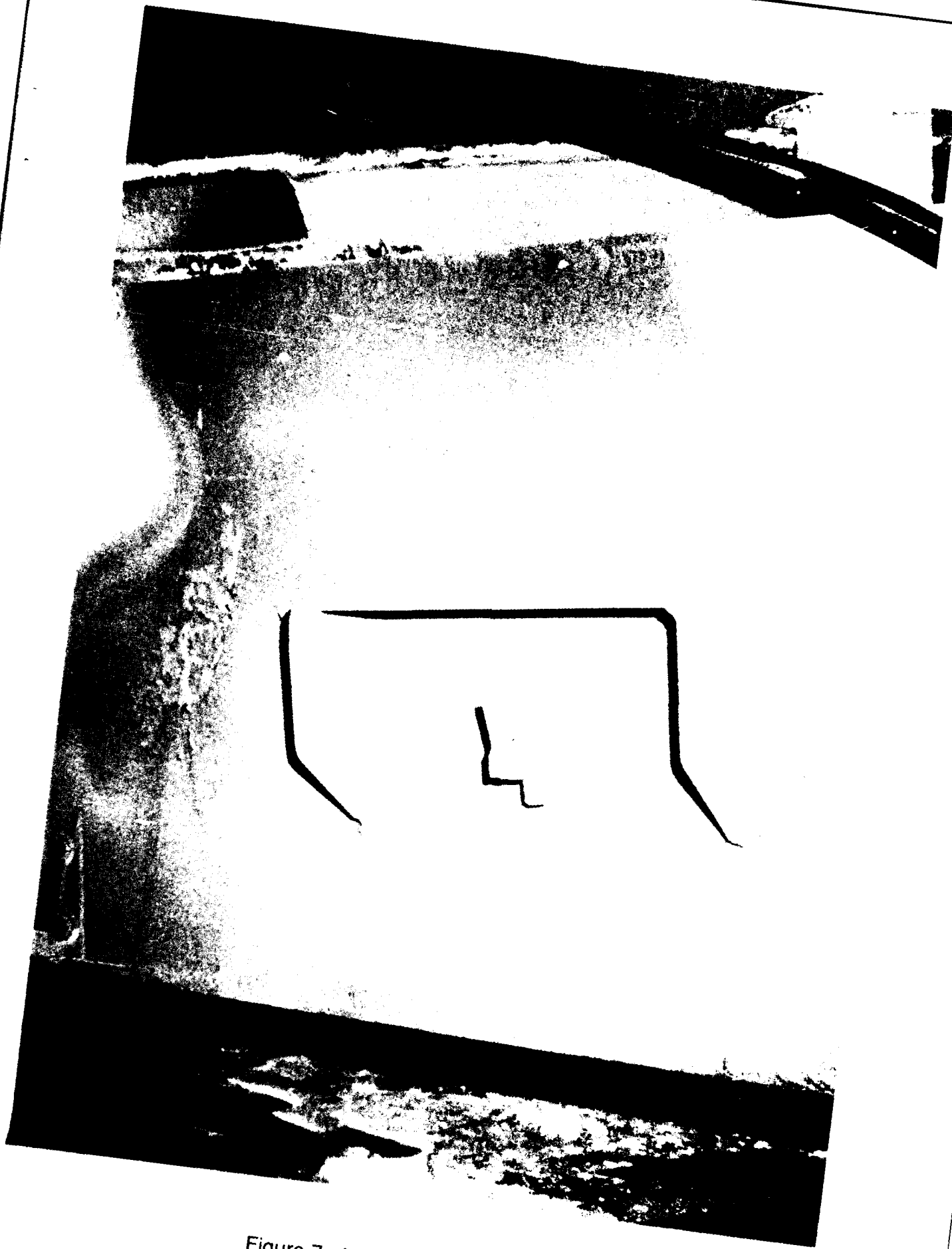


Figure 7. Installed toggle valve

# **M198 HOWITZER EQUILIBRATOR ADJUSTING SCREW ASSEMBLY**

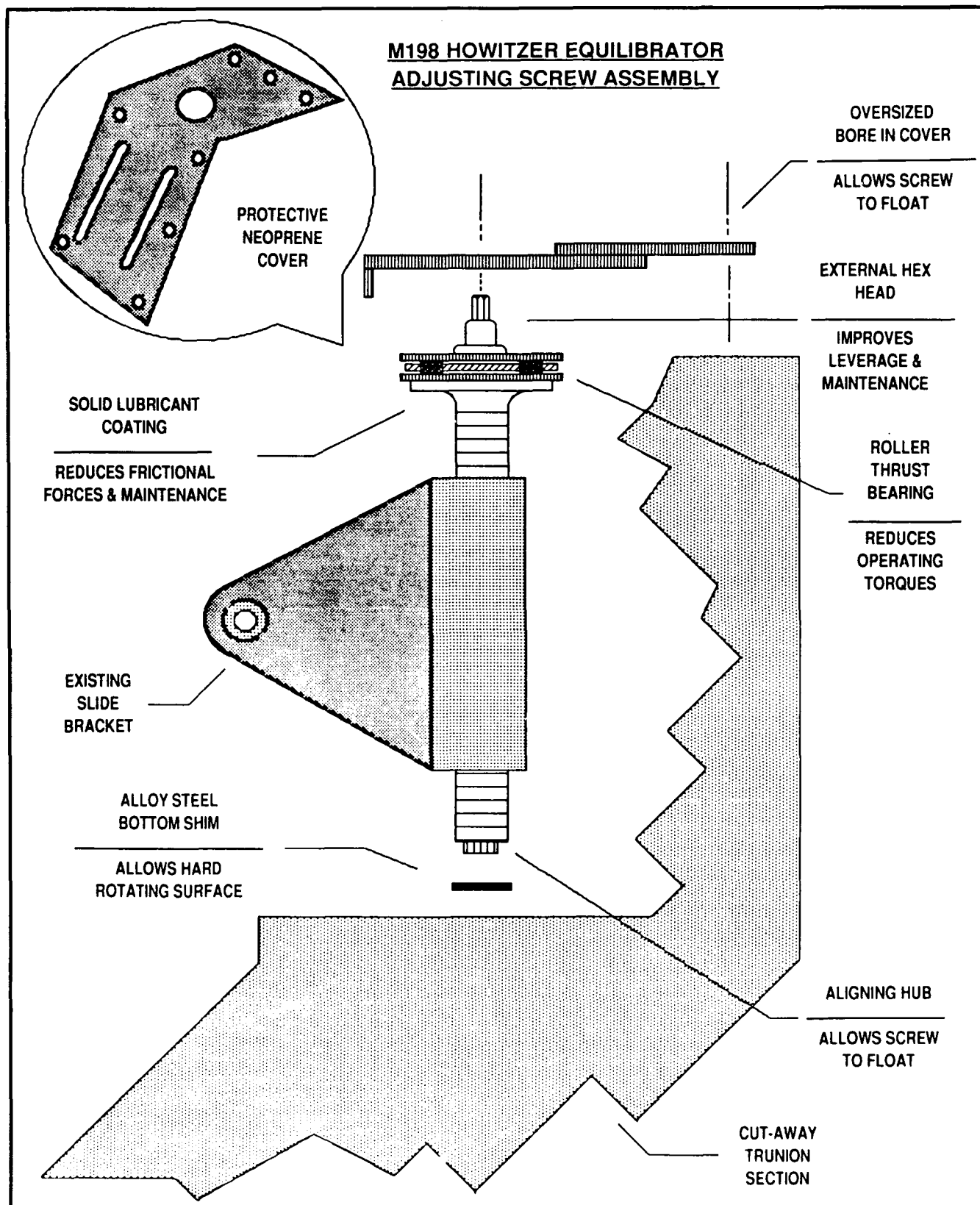


Figure 8. Equibrator adjusting screw assembly

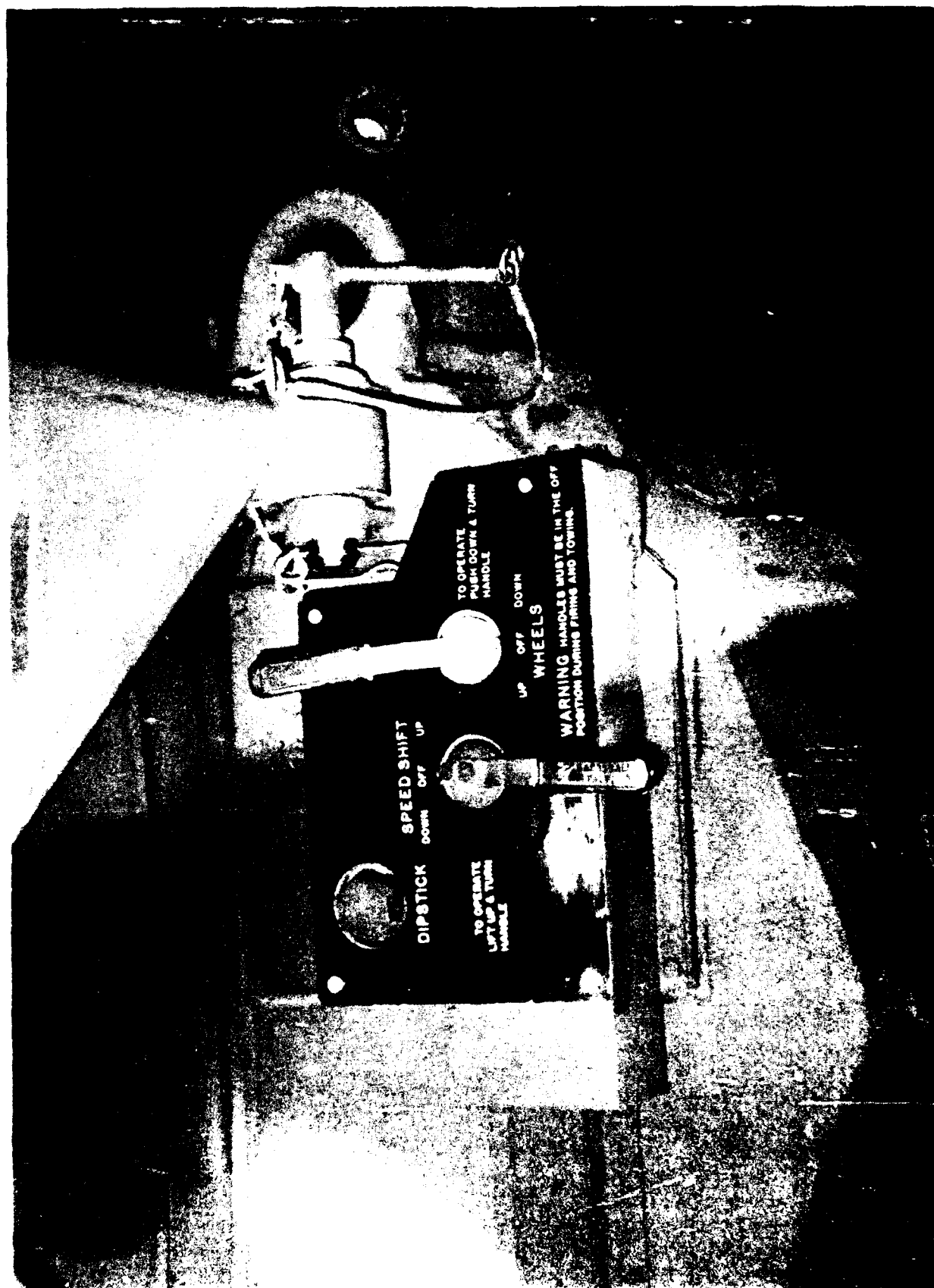


Figure 9. Hydraulic selector valves

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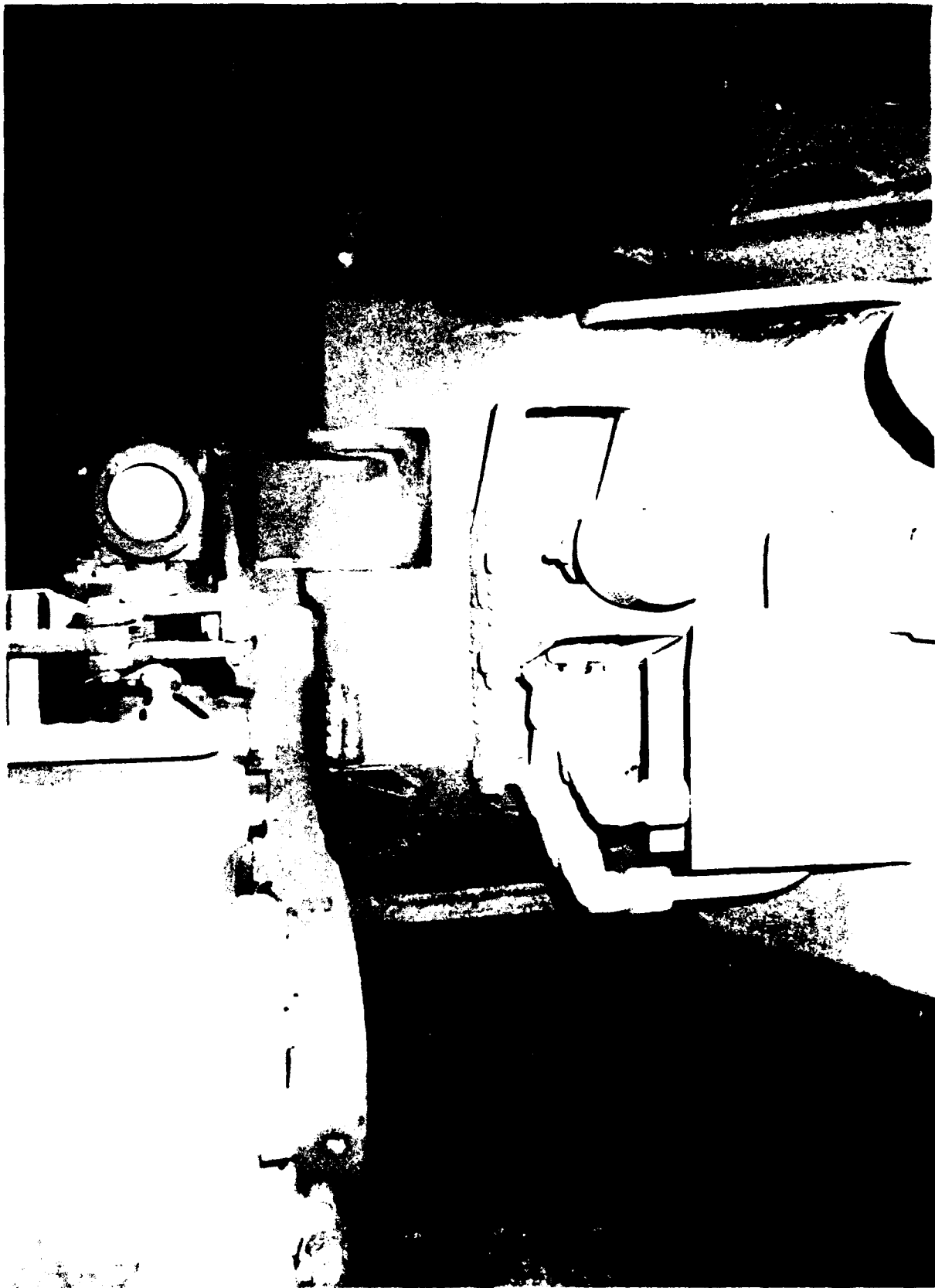


Figure 11. Installed hydraulic pump



Figure 12. Traverse locking pin assembly



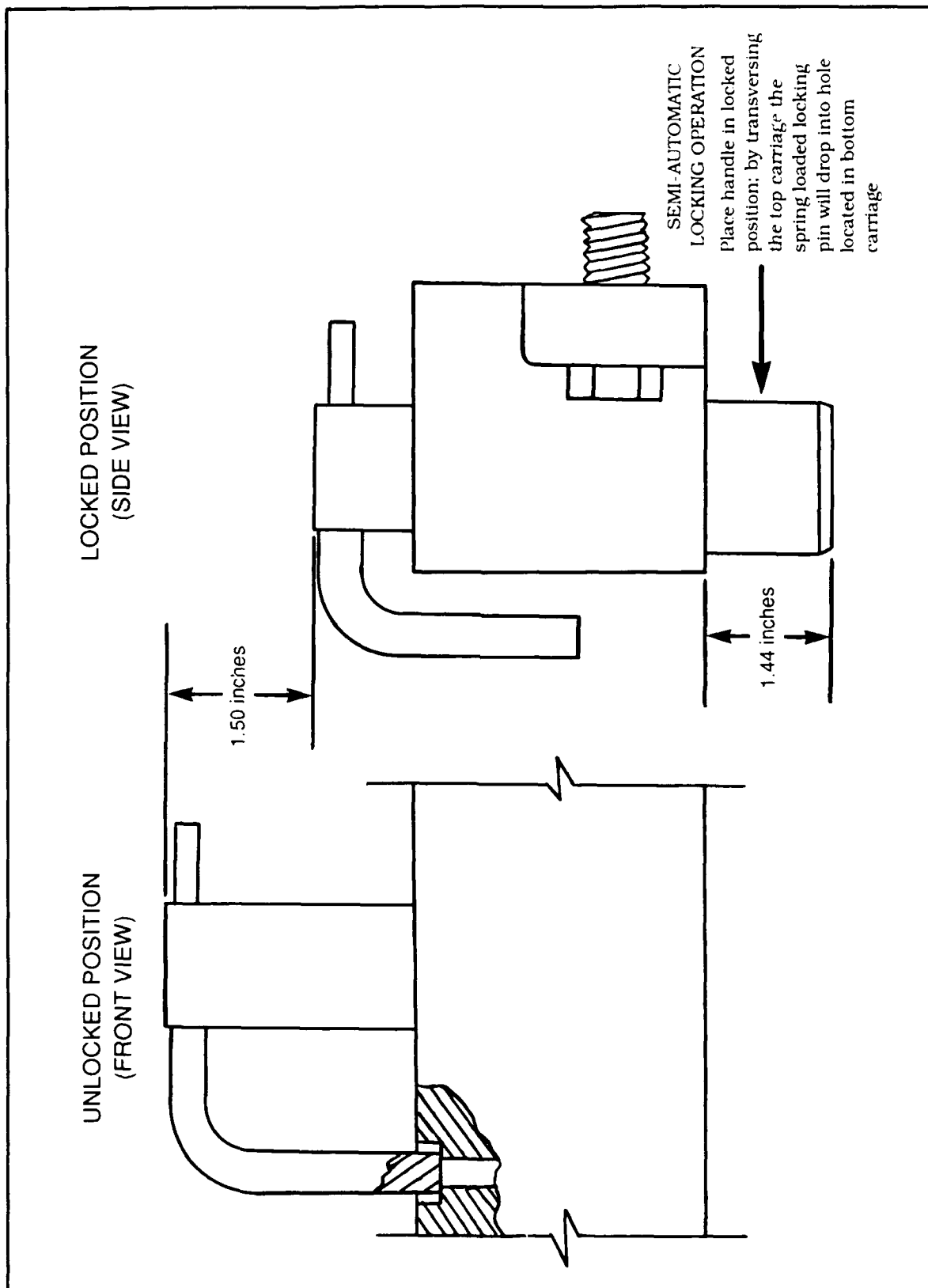


Figure 13. Operating positions of locking pin assembly



Figure 14. Trail locking assembly



Figure 15. Base plate locking handle

NOTES:

1. APPLICABLE STANDARDS/SPECIFICATIONS:
  - A. DOD-STD-001000 (AR).
  - B. ANSI Y14.5M-1982.
2. REMOVE (2) BRACKET-12008515  
CLEAN UP 85% MIN.
3. DRILL (2)  $\varnothing .78 \pm .01$  THRU HOLES AS INDICATED.
4. INSERT (2) TUBE-12909132 AS SHOWN.
5. WELD IN ACCORDANCE WITH CLASS 1, MIL-W-45202.
6. REMOVE ANY WELD SPATTER.
7. APPLY TOUCH UP PER FINISH NO. 81.1.  
PER DWG 9347218.
8. PMIC A
9. THIS DRAWING IS FOR INSTALLATION PURPOSES  
ONLY. ALL ITEMS ARE INCLUDED IN KIT.

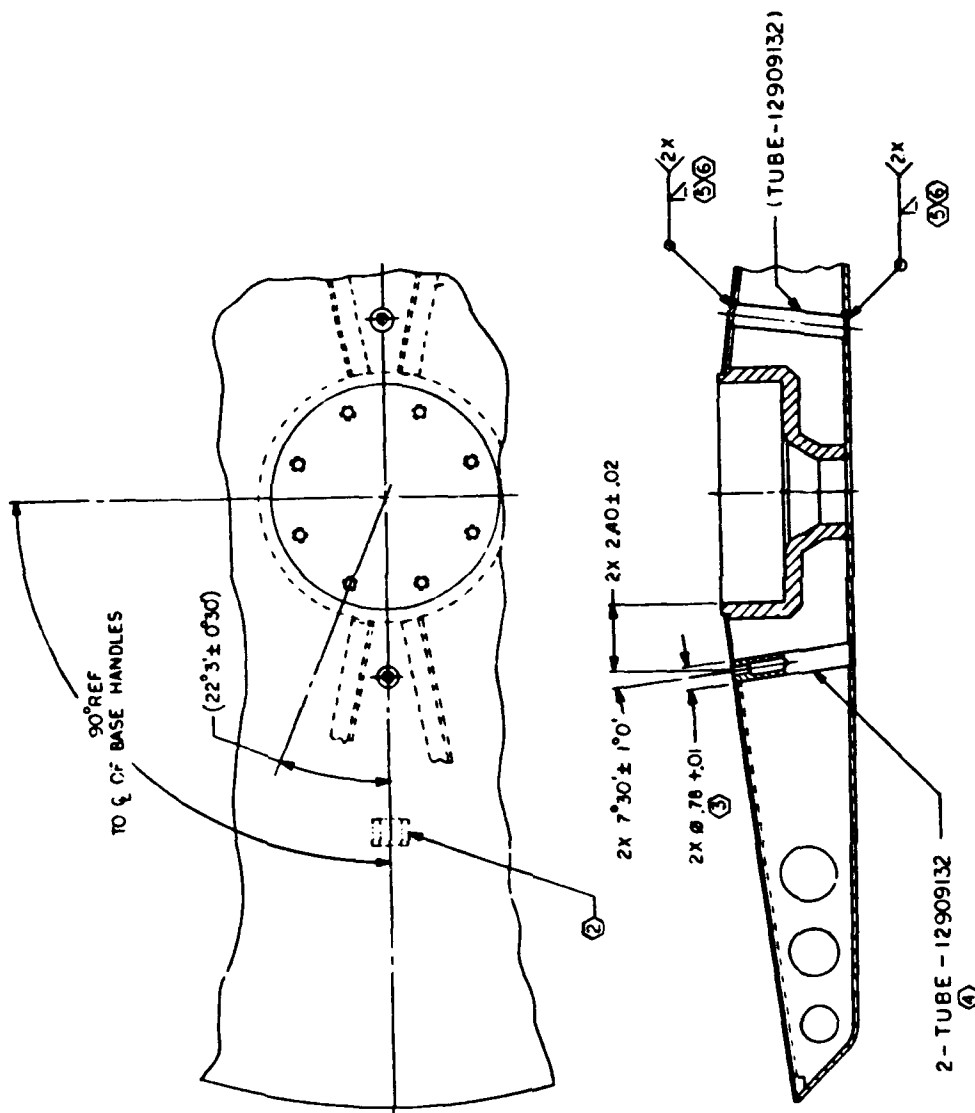
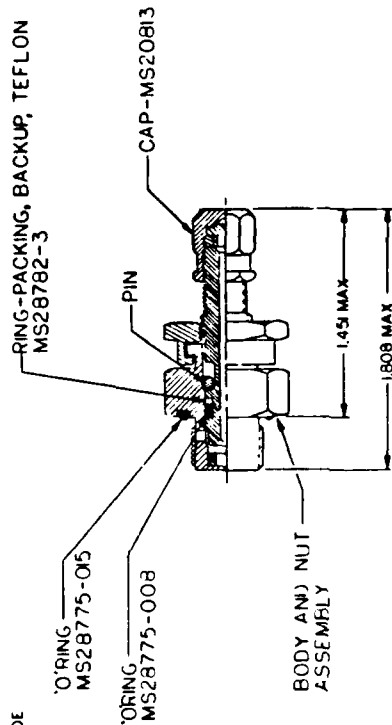


Figure 16. Base plate

NOTES

1. APPLICABLE STANDARDS / SPECIFICATIONS:  
A. DOD-STD-001000 (AR)  
B. AMS: Y14.5M-1982
2. REQUIREMENTS:  
A. MATERIAL-----STEEL-STAINLESS 303 OR 304  
AMS 5640 OR AMS 5641  
B. WORKING PRESSURE-----8,000 P.S.I. (MAX)  
C. CYCLE LIFE-----500 MIN.  
D. INSTALLATION TORQUE-----125 IN./LBS.  
E. SEALING TORQUE-----50+10 IN./LBS.
3. TEST VALUE IN ACCORDANCE WITH MIL-V-6164.
4. ITEM IDENTIFICATION OF THE SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM(S).
5. ITEM IDENTIFICATION APPLY THE FOLLOWING MIL-STD-130:  
19200-12909161  
MFR ----- MANUFACTURER'S CAGE CODE



SUGGESTED SOURCE OF SUPPLY				
PART NO.	ADDRESS	CAGE CODE	VENDOR PART NO.	ITEM IDENTIFICATION
12909161	HYDRO FITTING MFG CORP 713 EAST EDNA PLACE COVINA, CALIFORNIA 91723	13899	HF 2001	19200-12909161 MFR

Figure 17. Equilibrator/recuperator valve

- NOTES:
- 1- APPLICABLE STANDARDS/SPECIFICATIONS:  
 A DDD-STD-00100 AR  
 B ANSI Y14.5M-1982
  - 2 REQUIREMENTS:  
 A-MATERIAL: NEOPRENE/NYLON SEE NOTE 3  
 B-THICKNESS: .033 STOCK  
 C-TEMP RANGE: -40°F TO +130°F  
 D-EST LIFE: 50,000 FULL STROKE (24,20) CYCLES  
 E-COLOR: BLACK  
 F-MIN EXTENSION: 27.20  
 G-MAX COMPRESSION: 3.00  
 H-CONSTRUCTION: MOLDED
  - 3-MATERIAL MUST REMAIN PLIABLE THROUGHOUT THE ENTIRE TEMPERATURE RANGE.
  - 4-APPLY PART NO. PER MIL-STD-130.
  - 5-IDENTIFICATION OF THE SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM(S).
  - 6-SUGGESTED SOURCE(S) OF SUPPLY:  
 LONG ISLAND MACHINERY  
 133 EDWARDS AVE., P.O. BOX 509  
 SAYVILLE, NY 11782 516/563-12-7  
 PART NO. 062570-2  
 CAGE CODE 88759
  - 7-PMIC-A

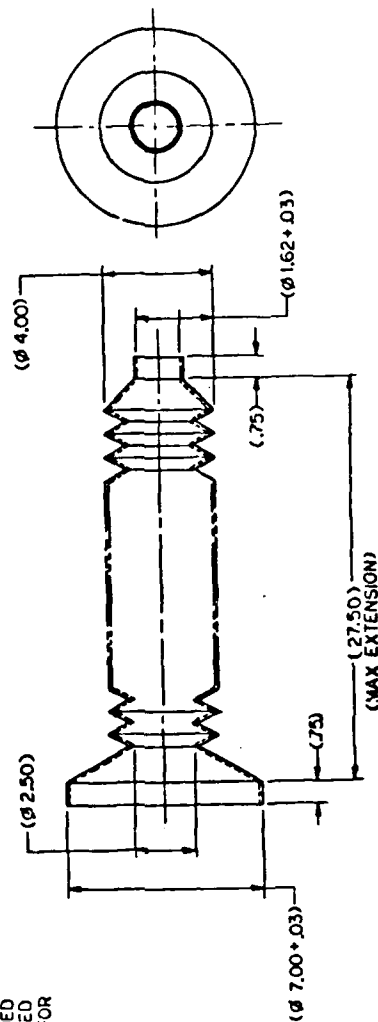


Figure 18. Equilibrator bellows

- NOTES:
1. APPLICABLE STANDARDS/SPECIFICATION:
    - A. DDD-STD-001000 (ARI)
    - B. ANSI Y43M-1982
  2. REQUIREMENTS:-
    - A. MATERIAL:-NEOPRENE/NYLON(SEE NOTE 3)
    - B. THICKNESS: .033" STOCK
    - C. TEMP RANGE: -40°F TO +130°F
    - D. EST. LIFE: 50,000 FULL STROKE (5") CYCLES
    - E. COLOR: BLACK
    - F. MIN. EXTENSION: 6.38
    - G. MAX. COMPRESSION: 1.38
    - H. CONSTRUCTION: MOLDED
  3. MATERIAL MUST REMAIN PLIABLE THROUGHOUT THE ENTIRE TEMPERATURE RANGE.
  4. APPLY PART NO. PER MIL-STD-130.
  5. IDENTIFICATION OF THE SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM(S).
  6. SUGGESTED SOURCE(S) OF SUPPLY:
    - A. AND A MFG. CO., INC.
    - 2300 S. CALMOUND ROAD
    - NEW BERLIN, WISCONSIN 53151
    - PART NO. 062570-1
    - CAGE NO. 88759
  7. PWC A

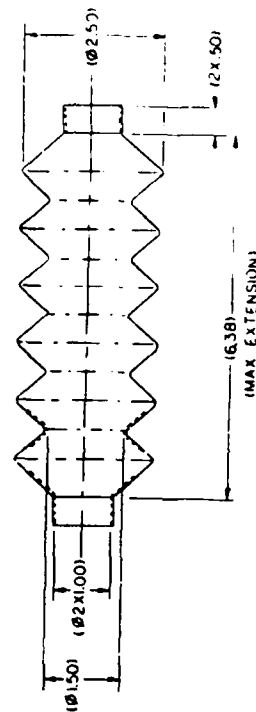


Figure 19. U-joint bellows



Figure 20. Spade key retention bracket



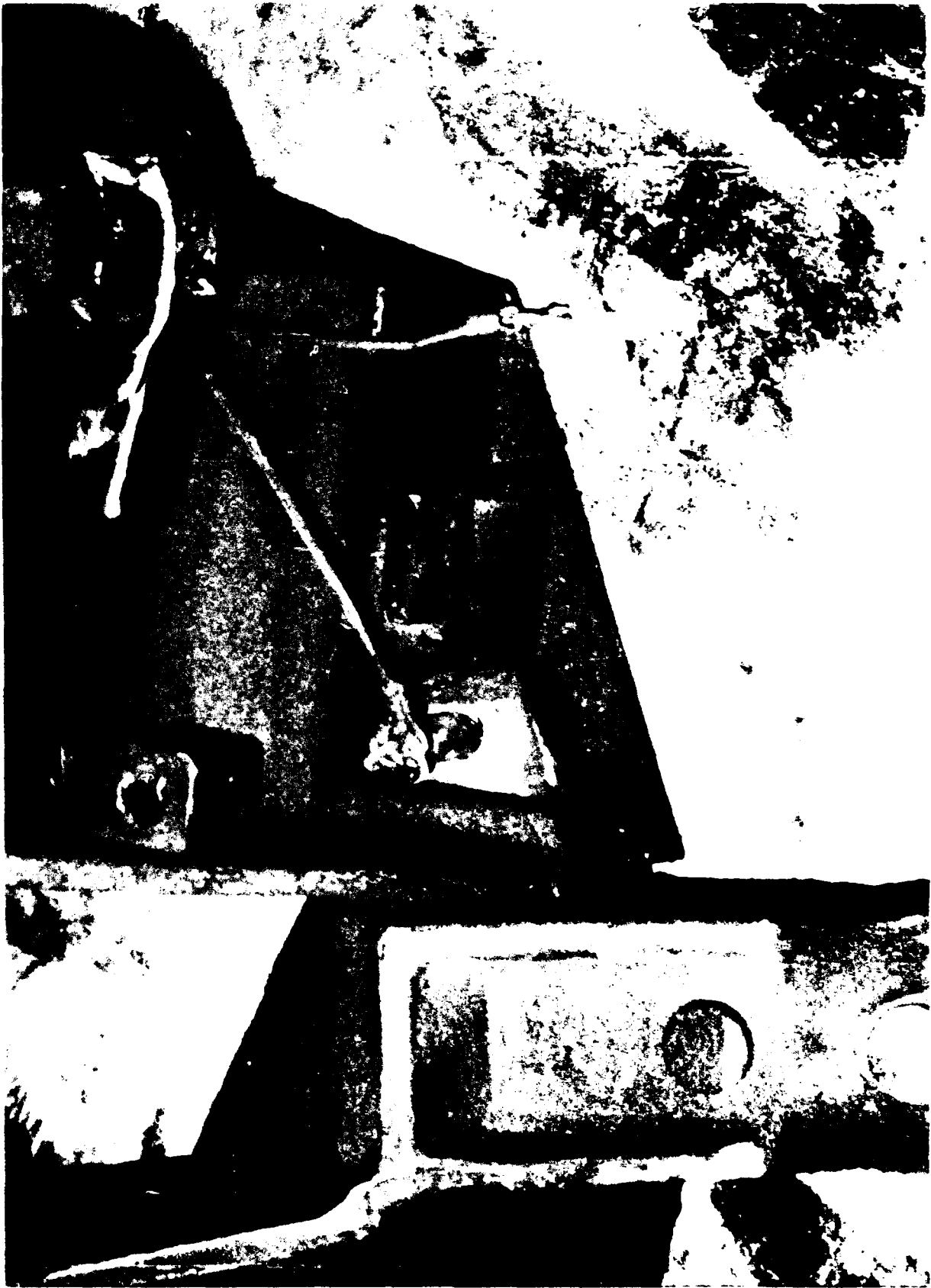


Figure 21. Trail locking pin linkage assembly

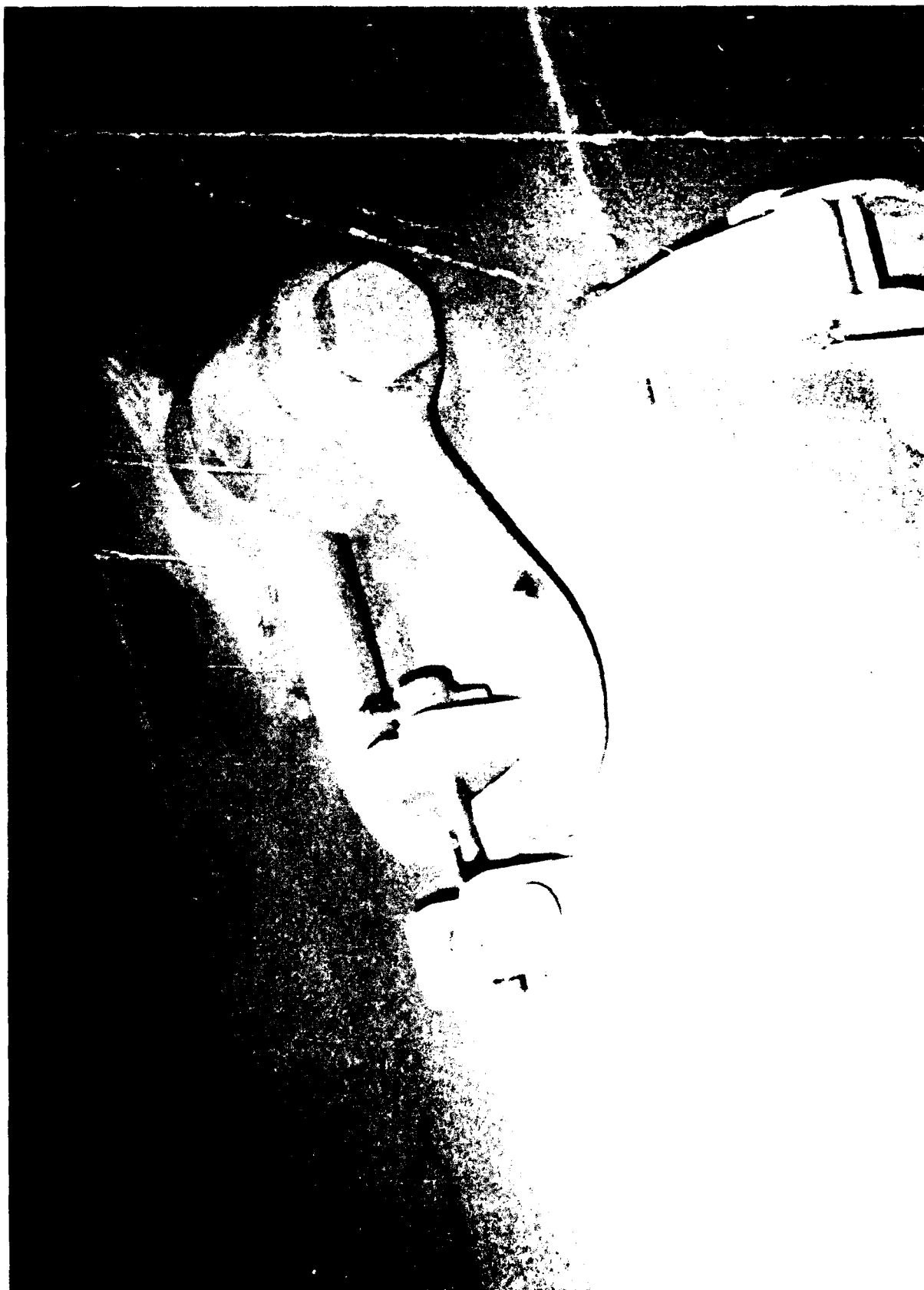


Figure 22. Eye bolt retention assembly

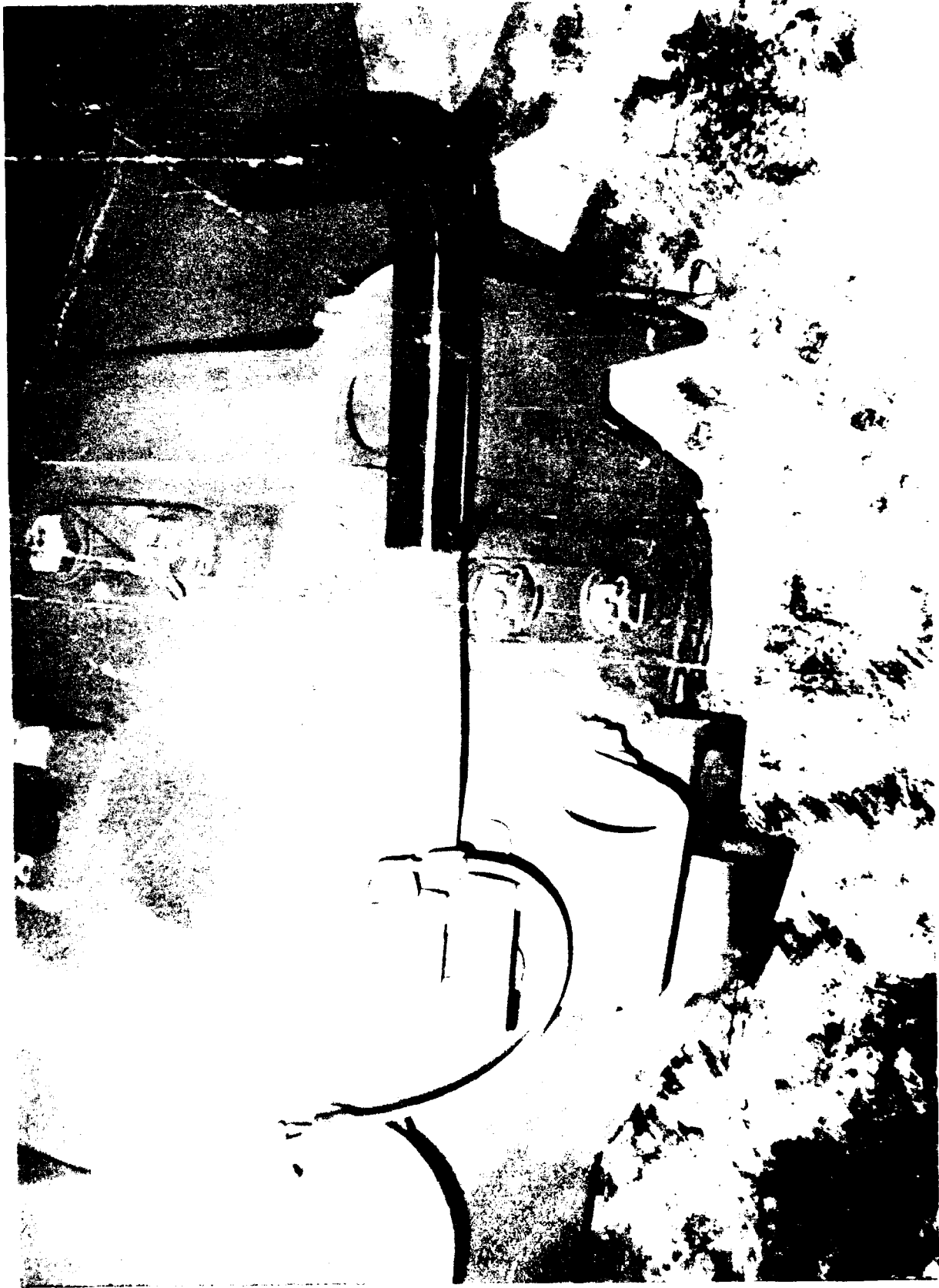


Figure 23. Swing handle assembly



Figure 24. Standoff

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OVERVIEW

Charles Widmer  
Lisa Weland  
Kenneth Heider  
Gray Paulter  
Wesley Rose  
Joseph Sankner

April 1991

1992

Attach new cover with spelling correction of Charles Widmer's name.

Insert SF 298 into report as the title page.

June 1992

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